

# Analysis of Microstrip Antenna Loaded with High Impedance Ground Plane Frequency Selective Surface

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**Abstract**—A rectangular microstrip antenna loaded with high impedance ground plane frequency selective surface (FSS) is presented in this paper for gain enhancement. The EM analysis is carried out using equivalent circuit model. The proposed antenna exhibits high input impedance as compared to the microstrip antenna at 10 GHz. Further, the radiation characteristics of the FSS-loaded antenna are analyzed at 10 GHz. It is observed that the proposed antenna offered 1 dB gain enhancement in elevation plane as compared to the conventional microstrip antenna.

## I. INTRODUCTION

The frequency selective surfaces (FSS) structures have been widely used as spatial filters in various applications such as radome, RAS, reflector antennas, microwave circuits, etc. In these applications, FSS technology is mainly employed to enhance the performance and reduce the RCS of the candidate device. Based on the transmission characteristics of the FSS, it can be classified into two categories namely, band-pass FSS and band-stop FSS [1]. The band-pass FSS is severally used as radome for antennas to enhance its performance and reduce the RCS of antenna [2-3]. In contrast, there are only a few reports on the RCS reduction using stop-band FSS.

Recently, FSS is used as superstrate or high impedance ground plane in planar antennas to enhance its gain and RCS reduction [4]. Antennas such as dipoles, microstrip patches, etc., need a ground plane which acts as a reflector to enhance the radiation gain. But the metallic ground plane is one of the most important scattering components of the antenna because it largely reflects the energy of incident waves [5]. In order to reduce the scattering component and hence to enhance the radiation gain of the microstrip antenna, the conventional ground plane can be replaced with a stop-band FSS.

In view of this, the EM analysis of microstrip patch antenna loaded with stop-band Jerusalem cross FSS ground plane based on equivalent circuit method is presented in this paper. The proposed microstrip antenna exhibits high input impedance and significant gain enhancement (1dB) in elevation plane at 10 GHz.

## II. THEORETICAL ASPECTS

The side view of rectangular microstrip antenna loaded with FSS ground plane is shown in Fig. 1, where stop band Jerusalem cross FSS acts as the high impedance ground plane for the antenna. The analysis of proposed antenna is carried out based on equivalent circuit model. Accordingly, a rectangular microstrip patch antenna can be represented as the parallel RLC resonant circuit, where  $R$  represents the ohmic loss in metallic parts of patch,  $L$  and  $C$  represent the inductance and capacitance due to the magnetic and electric energy stored in the antenna, respectively. Based on this method, a FSS structure can be represented as  $LC$  resonant circuit. The equivalent circuit of proposed microstrip antenna is shown in Fig. 2, where impedance offered by FSS is considered as series impedance to the patch antenna impedance.

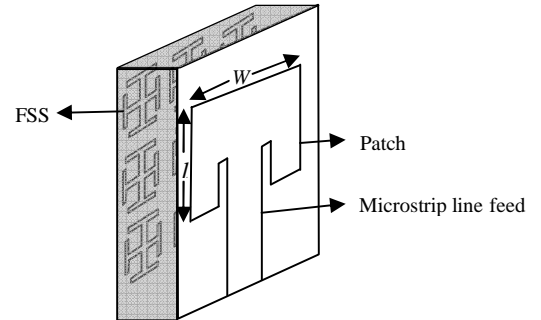


Figure 1 Side view of rectangular microstrip patch antenna loaded with FSS

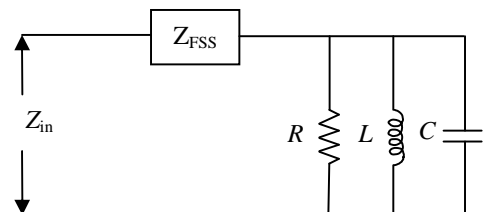


Figure 2 Equivalent circuit of microstrip patch antenna loaded with FSS

The input impedance of a rectangular microstrip patch antenna can be expressed by [6]

$$Z_a = \frac{1}{\frac{1}{R} + j\omega C + \frac{1}{j\omega L}} \quad (1)$$

where,  $R$ ,  $L$ , and  $C$  are the equivalent resistance, inductance and capacitance of microstrip antenna, respectively and is given in [6].

Since the Jerusalem cross FSS is comprised of capacitive and inductive elements and hence its equivalent reactance can be expressed by [7]

$$X_g = X(w) - \frac{1}{B(g, t)} \quad (2)$$

where,  $X(w)$  and  $B(g, t)$  represents inductive and capacitive reactance, respectively, given in [7]. The impedance of the Jerusalem cross FSS is determined by

$$Z_{FSS} = \frac{jX_g}{1 + jX_g} \quad (3)$$

From Fig. 2, the input impedance of proposed antenna is given by

$$Z_{in} = Z_a + Z_{FSS} \quad (4)$$

### III. EM DESIGN ASPECTS AND PERFORMANCE ANALYSIS

In the present work, the proposed antenna is designed at the operating frequency of 10 GHz. The design parameters of the antenna are determined based on cavity model. The length and width of the patch are 9.06 mm and 11.86 mm, respectively. The height of the substrate is 1.588 mm and dielectric constant is 2.2. The Jerusalem cross FSS is also designed at 10 GHz for band-stop characteristics. The design parameters of the FSS are; periodicity,  $p = 7.3$  mm, width of the inductive strip,  $w = 0.9$  mm, length of each cross,  $d = 5.01$  mm, width of each cross,  $h = 0.3$  mm, and separation between adjacent crosses  $g = 0.21$  mm. From Fig. 3, it is observed that the input impedance of the proposed antenna is higher than the rectangular patch antenna alone.

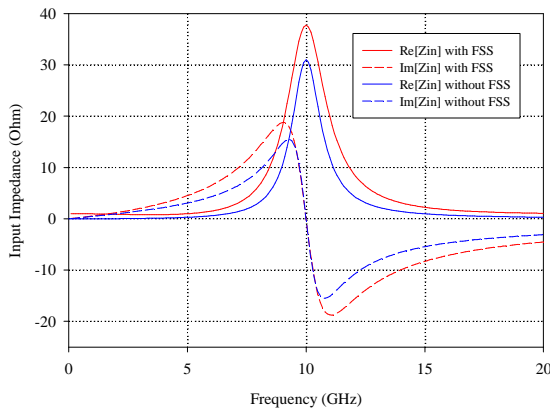


Figure 3 Input impedance of microstrip antenna loaded with FSS

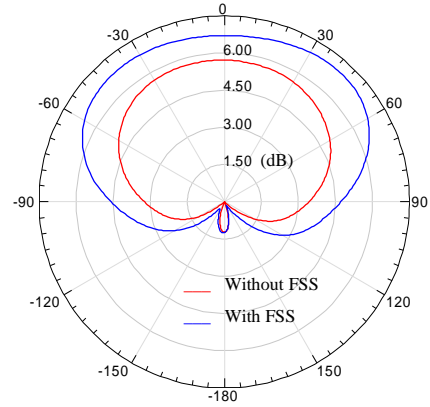


Figure 4 E-plane radiation pattern of microstrip antenna loaded with FSS

The radiation pattern of proposed antenna is determined using FEM based HFSS simulation software and compared with that of rectangular patch antenna alone as shown in Figure 4. It is observed that the loading of FSS as high impedance ground plane of antenna enhances its gain by 1 dB and also enhances the beam-width significantly.

### IV. CONCLUSIONS

In the present work, analysis of microstrip antenna loaded with high impedance ground plane FSS is carried out based on equivalent circuit model. It is concluded that the loading of FSS as ground plane of antenna offered high impedance and hence enhanced its gain by 1 dB compared to the conventional rectangular patch antenna at 10 GHz. The proposed FSS based patch antenna can be used as low profile and low RCS antenna for stealth applications.

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